LOAD-BEARING STRUCTURE REVERSIBLY FLEXIBLE AND RIGID

Filed May 8, 1964

FIG. 1

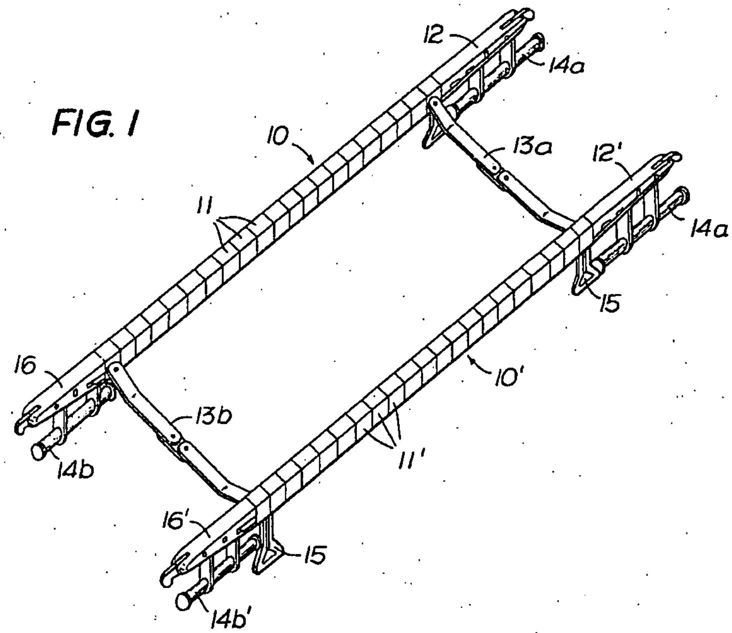


FIG. 7

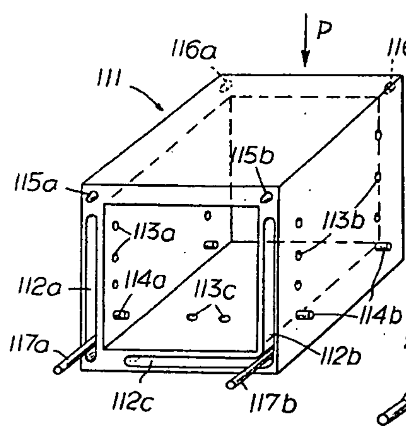
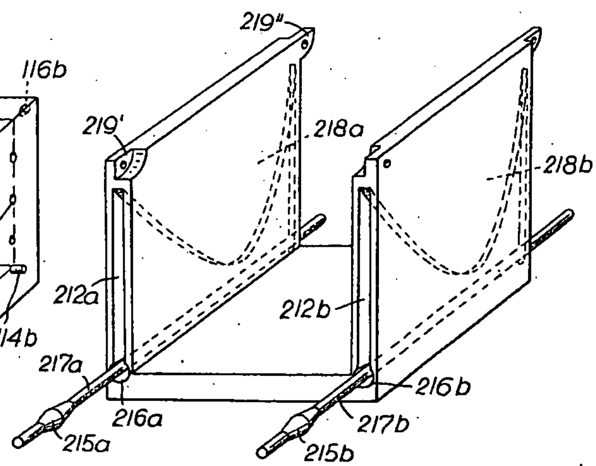


FIG. 8



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April 18, 1967 W. SCHUSTER 3,314,200

LOAD-BEARING STRUCTURE REVERSIBLY FLEXIBLE AND RIGID

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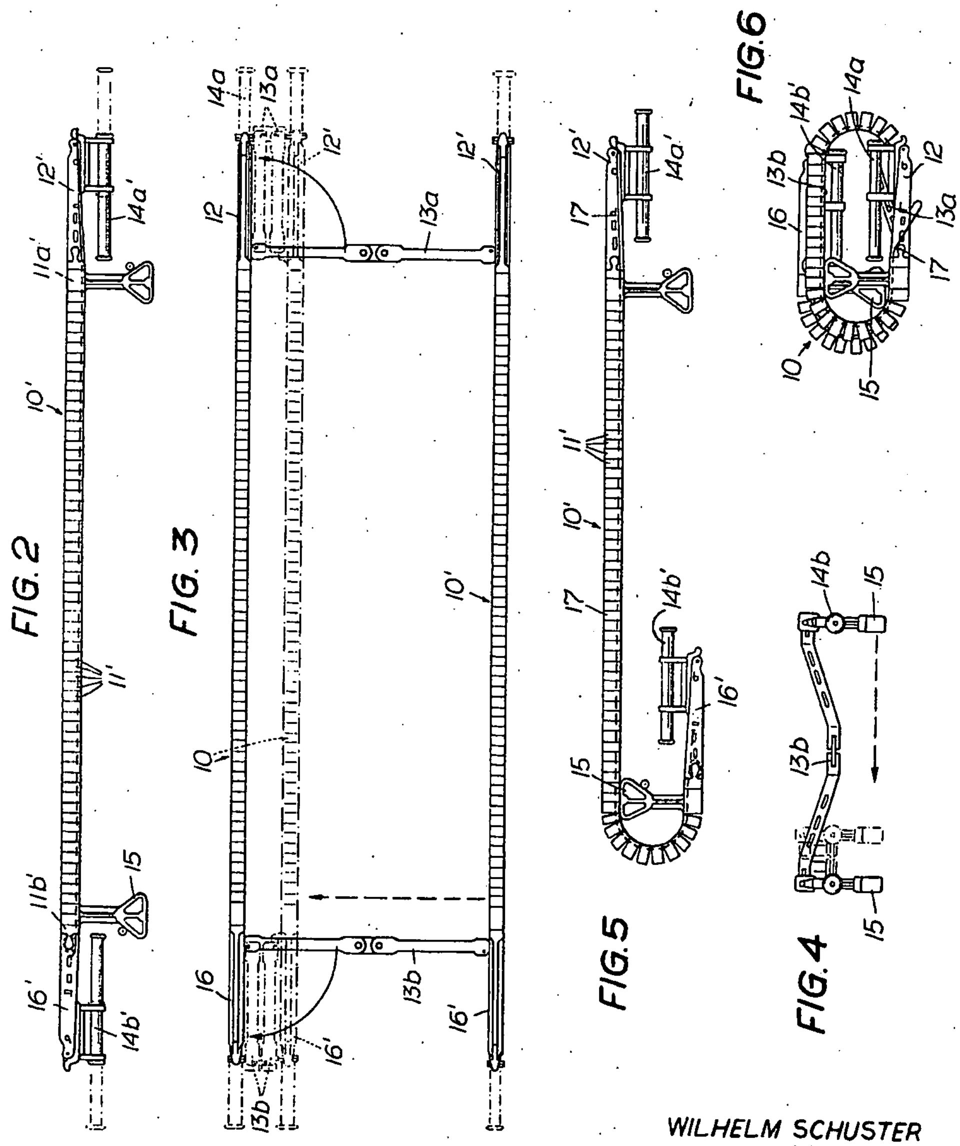

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LOAD-BEARING STRUCTURE REVERSIBLY FLEXIBLE AND RIGID

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FIG. 9

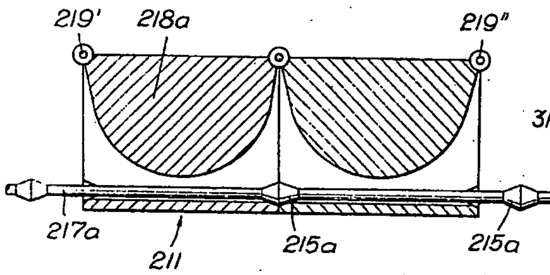


FIG. 11

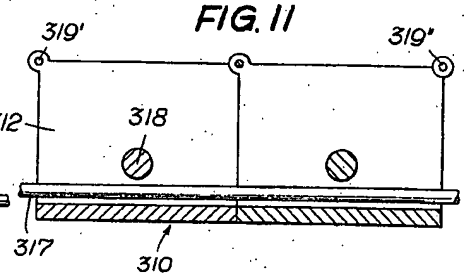


FIG. 10

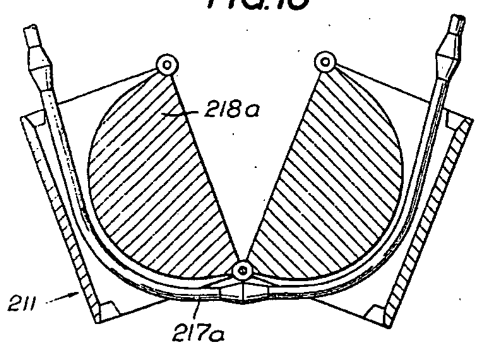


FIG. 12

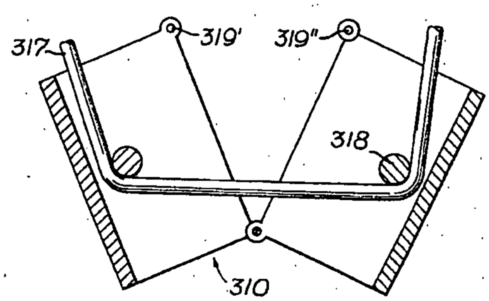
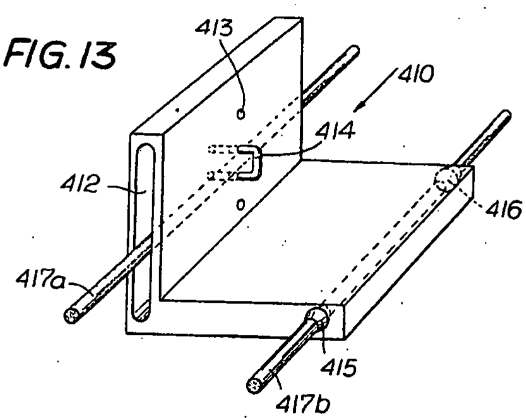


FIG. 13



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LOAD-BEARING STRUCTURE REVERSIBLY FLEXIBLE AND RIGID

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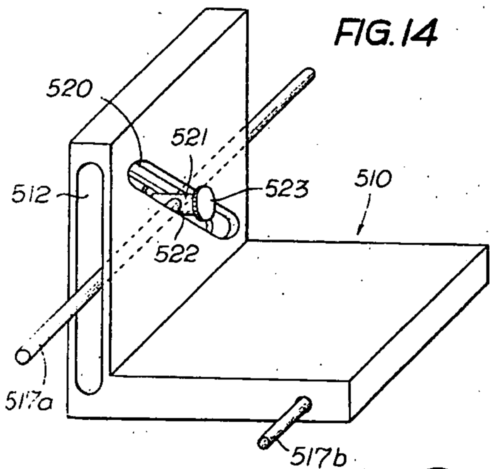

FIG. 14

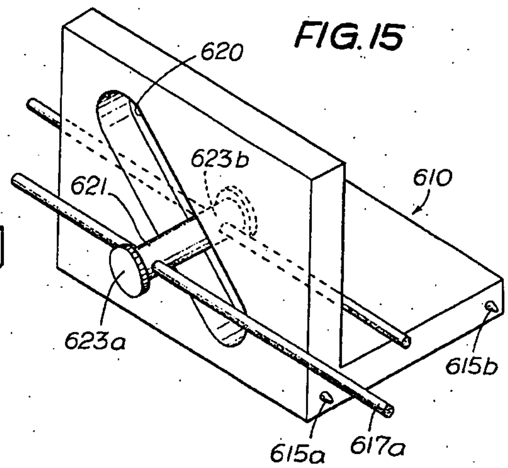

FIG. 15

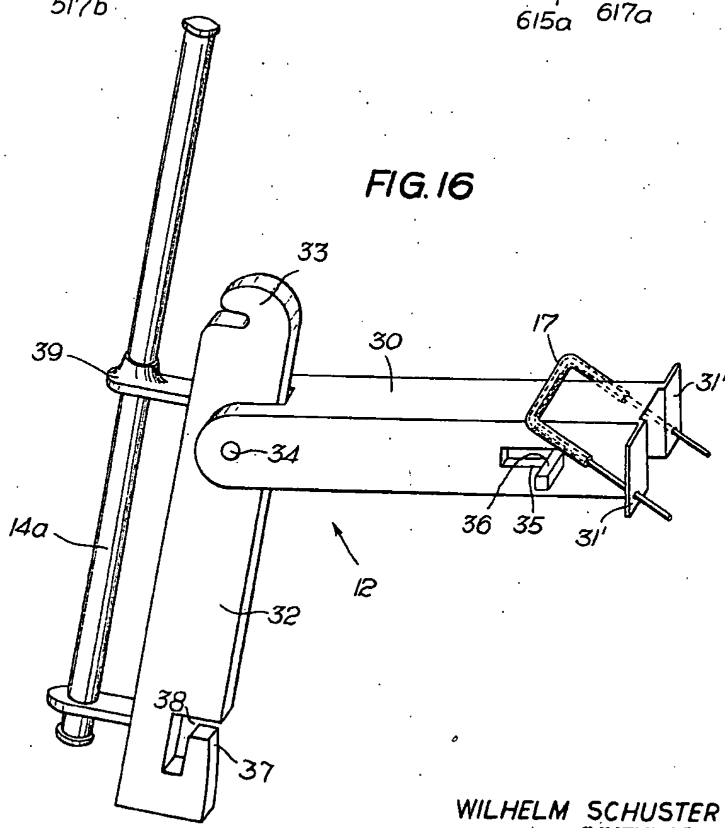

FIG. 16

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LOAD-BEARING STRUCTURE REVERSIBLY FLEXIBLE AND RIGID

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Filed May 8, 1964, Ser. No. 366,100

Claims priority, application Austria, Dec. 4, 1959, A 8,802/59

13 Claims. (Cl. 52—108)

The present application is a continuation-in-part of my copending application Ser. No. 72,837, filed Nov. 29, 1960 and now abandoned.

This invention generally relates to collapsible assemblies of loosely interconnected members which may be selectively stiffened into rigid bodies or relaxed for storage or transport. Such structures have been disclosed in my prior Patent No. 2,822,896, issued Feb. 11, 1958, and consist basically of a plurality of aligned body sections of limited length, reminiscent of the vertebrae in a human spine, which are held together under pressure by releasable tension elements.

The structures of this type disclosed in my above-identified prior patent utilize annular body sections interconnected by one or more tension elements symmetrically disposed with reference to the body axis. Assemblies consisting of such sections are well suited as vertical supporting rods or the like in which there is no preferred direction of flexural stress. They do, however, require a considerable bending radius when being rolled up in their relaxed condition. In turn, the relatively large slack of the tension means to be taken up in the tightened condition necessitates tightening devices having a long stroke. Their utility as structural elements is further limited by the fact that the sections and tension elements cannot be adjusted relatively to one another to compensate for given stress conditions and that there exists no convenient way of combining a plurality of units into composite structures.

Accordingly, it is an object of my present invention to provide collapsible structures of the type referred to in which means are provided to enable relative transverse adjustment of the body sections and their tension elements in order to combine maximum structural rigidity in the tensioned state with a large degree of flexibility in the relaxed condition of the assembly.

A related object of the invention is to provide such structures with simple means for relatively immobilizing their body sections and tension elements in different positions of adjustment, e.g. for the purpose of shifting the zone of maximum compression to accommodate different stress conditions under load.

Still another object of the invention is to provide an improved device for tightening one or more tension elements (especially a pair of such elements) in structures of this type, in combination with means for locking the device in its operated position.

According to this invention I provide, in an assembly of interconnected body-forming members as described above, at least one elongated, flexible and substantially inextensible tension element which is so shiftable with reference to each individual body member as to come to rest at different distances from one of the lateral surfaces of the member, i.e. the surface located at that side of the structure toward which the latter is to be rolled or folded in its slackened state. Thus, the tightened tension element can be positioned at a sufficient distance from that side to provide a strong moment of resistance against bending in the solidified structure but, when slackened, can be brought close enough to one of the surfaces of each body member to permit coiling of the assembly about a small radius.

According to a more specific feature of this invention, each of the body members bearing upon one another in pressure-transmitting relationship is formed with a wall extending substantially perpendicularly to the aforementioned surface, this wall thus lying at least approximately in the plane of flexure, and at least one tension cable is disposed next to this wall in a space affording clearance for the shifting of the cable along the wall surface. Such shifting may be temporarily prevented by removable stops, e.g. pins attached to the wall, though it is also possible to provide a permanent abutment which engages the cable at a single point, remote from the side facing in the direction of bend, while letting the cable flex around that point toward the side proximal to the center of curvature when adjacent members are swung relatively to one another, in the relaxed state of the cable, about axes transverse to the plane of flexure.

The system according to the invention enables the rigid unit so obtained to be used as a more or less horizontal beam which, when loaded, will have a lower tension flange and an upper compression flange, the cable or cables being situated in the region of the tension flange to absorb the negative stresses due to bending moments. A tightening device for the cable or cables may then comprise a simple toggle lever adapted to be swung from a released position into an operated position alongside the tension flange, the lever being securely held in the latter position by the stretched cable whose elastic force is supplemented by the loading stresses; if desired, however, a safety catch may be added to prevent any untimely release of the lever even when the load is removed.

The displaceability of the tension cable or cables, besides enabling a shift in the compression zone to suit different types of load, also allows adjacent body members to be articulatedly interconnected by suitable hinges or the like, for structural continuity, in the region of the compression flange which in operation is remote from the cable position. When the cable is released to collapse the unit, a displacement of the cable toward the hinges will facilitate coiling of the assembly without putting a strain on the linkage between the members. Where a positive coupling of these members to one another is desired only in the rigid condition, the hinges may be replaced by interfitting formations on confronting faces of adjoining members.

An important advantage of this invention is that composite articles, incorporating one or more elongated structural units of the type described, may be folded or rolled up bodily in a preferred direction regardless of the operating position of the tension element or elements within each unit. A foldable stretcher, for example, may include a frame with side bars composed of abutting body sections that are held together by respective pairs of tensionable internal cables extending horizontally near the bottom surface of each bar; such a stretcher could readily be rolled up in a downward direction upon a slackening of the cables, yet it could also be coiled upwardly—should this be preferred—if the cables were vertically shiftable inside the body sections as discussed above.

The foregoing features, partly disclosed in my aforementioned application Ser. No. 72,837, will become more fully apparent from the following detailed description of certain embodiments, reference being made to the accompanying drawing in which:

FIG. 1 is a perspective view of a stretcher frame embodying my invention;

FIG. 2 is a side view of the frame in its rigid state;

FIG. 3 shows the partly collapsed stretcher frame in a top view;

FIG. 4 is an elevational front view of the frame;

FIG. 5 shows the frame of FIGS. 1–4 partially rolled up, in a side view;

FIG. 6 shows the stretcher frame completely rolled up for storage, in a side view;

FIG. 7 is a perspective view of an advantageous embodiment of a body section adapted to be used in a frame as shown in the preceding figures;

FIG. 8, in a view similar to that of FIG. 7, shows a modified body section;

FIG. 9 is a longitudinal sectional view of two interconnected body sections of the type shown in FIG. 8, taken on the line IX—IX thereof;

FIG. 10 shows the sections of FIG. 9 in a similar view, but in a relaxed state of an associated pair of tension cables;

FIG. 11 is a view similar to FIG. 9 illustrating still another modification;

FIG. 12 shows the sections of FIG. 11 in a relaxed state in a view similar to FIG. 10;

FIG. 13 illustrates yet another form of body section in a perspective view;

FIG. 14 represents a perspective view of a further modification;

FIG. 15 depicts yet another variant, seen in perspective; and

FIG. 16 is a perspective detail view of a combined handle and tightening device employed in the frame of FIGS. 1–6.

In FIGS 1–6, I have shown a stretcher frame embodying my invention. Two elongated structural members **10, 10′** comprise each a plurality of body sections **11, 11′**. These sections are interconnected by tension cables **17** anchored at one end to a pair of tightening devices **12, 12′** which have actuating elements **14a, 14a′** designed as carrying handles for the stretcher. The other ends of the cables are attached to end stops **16, 16′** which, for convenience of manufacture, are of the same basic shape as the devices **12, 12′** and which are also associated with carrying handles **14b, 14b′**. Articulated cross-links **13a, 13b** are hinged to the terminations **12, 12′** and **16, 16′** of members **10, 10′** and serve to space these members horizontally apart during use of the stretcher; they are horizontally foldable at the center for reducing the separation of members **10, 10′** to a minimum when the stretcher is collapsed. Legs **15** depend from end sections **11a, 11a′, 11b, 11b′** to support the stretcher. It will be understood, although not specifically shown in the drawing, that a canvas or the like may be fastened by suitable means to the members **10, 10′** in order to provide support for a load to be placed on the stretcher.

The stretcher frame, shown in its rigid state in FIGS. 1 and 2 and partially collapsed in FIGS. 3 and 4, is seen in FIG. 5 in the process of being rolled up. One end of the structural member **10′**, with the tightening device **12′** attached, is shown swung downwardly in the direction of those body surfaces along which the tension element **17** is disposed, hence this arrangement requires but a small bending radius.

FIG. 6 shows the stretcher fully rolled up, the tension element **17** released and the handles (only those designated **14a′, 14b′** being visible) disposed inwardly of the relaxed elements **10, 10′**.

FIG. 16 is a detail view of the tightening device **12** with its carrying handle **14a**. A channeled bracket **30** comprises at its rear end two flanges **31′, 31″** through which the tension element **17** extends. At its other end a lever **32**, having a hook formation **33**, is fulcrumed at a point **34**. This lever is integral with the carrying handle **14a**. A latch **36** is horizontally slidable in a slot **35** extending transversely through the bracket **30**. Latch **36** is urged in the direction of the flanges **31′, 31″** by a spring (not shown). In operation, the looped end of the slack tension element **17** is slipped around hook **33** and lever **32** is pivoted counterclockwise into nesting position within the bracket **30**, thereby causing the latch **36** to be cammed forwardly by a lug **37** on that lever before being biased back into its original position to engage in the recess **38**, thus locking the lever in position. It should be noted that, in its tensioned state, the looped end of cable **17** lies somewhat below fulcrum **34** so as to tend to maintain the lever **32** in tightening position.

FIG. 16 also shows a pair of lugs **39**, rigid with lever **32**, in which the handle **14a** is axially slidable, the other handles **14a′, 14b, 14b′** being similarly mounted. It will be understood that the tensioning device **12** may also be used without the lugs **13** and the handle **14a** (or **14a′**) if this device is to serve only for the tightening of a cable without any carrying function.

In FIGS. 7–15 I have illustrated a variety of body sections which may be used as or in lieu of the members **11, 11′** in FIGS. 1–6.

The body section **111** shown in FIG. 7 is of prismatic configuration and provided in three of its walls with longitudinal slots **112a, 112b** and **112c**, the slot **112a** accommodating a tension cable **117a** whereas the two slots **112b** and **112c**, together constituting a channel of L-shaped profile, receive a cable **117b**. It will be understood that the two cables **117a, 117b** may be part of a single looped tensioning element as shown at **17** in FIG. 16. Each of the slotted walls of member **111** is provided with a set of throughgoing holes **113a, 113b, 113c** permitting the insertion of pegs, such as those shown at **114a** and **114b**, for holding the cables **117a, 117b** against transverse motion in selected positions within their respective channels **112a, 112b, 112c**. With the aid of these pegs, the plane of the parallel tension elements **117a, 117b** may thus be shifted up or down or even tilted into a nearly diagonal position, depending on the direction of the load to be sustained by the structure. With downwardly directed load pressures as indicated by the arrow P, for example, the illustrated bottom position of the cables **117a, 117b** will be most effective; if the load direction is subject to reversals, a positioning of the cables in or near a horizontal median plane will be more suitable. Approximately diagonal positioning, of course, will be preferred where the load acts in a direction other than vertical.

FIG. 7 also illustrates a pair of corner bosses **115a, 115b**, integral with the body of member **111**, which fit into complementary recesses **116a, 116b** of an adjoining member when several such members are interconnected to form an elongated structure as described in connection with FIGS. 1–6. It will be noted that the projections **115a, 115b** and the recesses **116a, 116b** are provided near the top of the member, thus in the portion thereof which forms a compression flange in the presence of a load as symbolized by arrow P. This load, which of course includes the dead weight of the elongated structure itself, prevents separation of the mating formations **115a, 115b** and **116a, 116b** in the tightened condition of the cables **117a, 117b**.

In FIGS. 8–10 I have shown another type of body section **211** which is of U-shaped profile and provided with longitudinal channels **212a, 212b** within the arms of the U, these channels accommodating a pair of tension cables **217a, 217b** as in the preceding embodiment. At their lower ends, i.e. in the region of the bight of the U, the channels **212a, 212b** are countersunk to form recesses **216a, 216b** accommodating complementary beads **215a, 215b** which slidably ride on the cables **217a, 217b** to form interfitting abutments between adjoining body sections, upon a tightening of the cables, as functional equivalents of the bosses **115a, 115b** of FIG. 7 (see particularly FIG. 9).

The channels **212a, 212b** are internally provided with curved ramps **218a, 218b** which descend from the top of the respective channel and approach the bottom of the channel, substantially midway along its length, with just enough clearance for the associated tension cable. The presence of these ramps positively locates the cables **217a, 217b** in their bottom positions upon the tensioning of the cables by the associated tightening device (FIG.

16); when the cables are relaxed, they can curve about the ramp surfaces so as to facilitate the swinging of adjoining members **211** about a small radius as illustrated in FIG. 10. It thus becomes possible to interconnect these members by means of mating hinge elements **219'**, **219"** so as to form a continuous articulated structure, such hinges being, of course, also usable in the embodiment of FIG. 7 (in lieu of the formations **115***a*, **115***b* and **116***a*, **116***b*) where the channels **112***a*, **112***b* allow the cables **117***a*, **117***b* to be slid towards these hinges preparatorily to the collapsing of the structure.

FIGS. 11 and 12 show part of a similarly articulated structure composed of U-shaped sections **310** which are hinged together at **319**, the principal difference between section **310** and **210** being that the ramps **218***a*, **218***b* have been replaced by a transverse pin **318** near the bottom of each cable-receiving channel **312**. The channel **312** in each arm of the U is upwardly open (in contradistinction to the channels **212***a*, **212***b* of FIG. 8) to permit a sliding of the relaxed cable **317** past the hinges **319'**, **319"** in the collapsed position illustrated in FIG. 12.

FIG. 13 shows a body section **410** of L-shaped profile with a single channel **412** for a cable **417***a* and a longitudinal bore holding the other cable **417***b* in transversely fixed position, this bore terminating in a recess **416** and in a complementary boss **415** slidably traversed by that cable. The channel wall of section **410** has again a series of throughgoing holes **413** adapted to receive suitable fastening means for temporarily immobilizing the cable **417***a*, such as a cable-straddling stirrup **414** or the pegs **114***a*, **114***b* of FIG. 7.

FIG. 14 shows a similar L-shaped section **510** with a longitudinal channel **512** for a cable **517** and a slanted throughgoing slot **520** intersecting that channel, the slot **520** being traversed by a stud **521** which has a cross-bore **522** through which the cable passes; a clamping screw **523** is threaded into an end of stud **521** to immobilize the latter with reference to cable **517***a* whereby the latter may be selectively held at any level of the inclined slot **520** and channel **512**. The other cable **517***b* is again fixedly lodged, except for longitudinal slidability, within the other leg of the L.

The L-shaped member **610** shown in FIG. 15 is similar to section **510** of FIG. 14, except that the longitudinal channel **512** is omitted from the leg of the L formed with the inclined slot **620**; the two cables **617***a* and **617***b*, flanking this leg of the L, are adjustably received in a single stud **621** (in the manner described for cable **517***a* in FIG. 14) which has two clamping screws **623***a*, **623***b*, on opposite ends, for immobilizing the cables with reference to the stud at a selected common level Bosses **615***a*, **615***b* are provided on the other leg for co-operation with complementary recesses in the manner and for the purpose described in connection with FIG. 7.

It will be apparent that the various types of body sections shown in FIGS. 7–15 have many interchangeable features which can be used in various combinations. Thus, for example, these sections can be hingedly interconnected, as in FIGS. 8–12, and/or provided with interfitting formations including recesses (**116***a* etc.) and projections (e.g. **115***a*, **215***a*, **415**, **615***a*) which may be located either at corners remote from the operative cable positions (FIGS. 7 and 15) or at points traversed by the cables (FIGS. 8, 9 and 13). In the latter case, again, the projections may be supported only by the cables or may be integral with one of two adjoining sections between which they are located. Other modifications and adaptations of the disclosed arrangements, readily apparent to persons skilled in the art, are also possible and are intended to be embraced in the spirit and scope of my invention as defined in the appended claims.

I claim:

1. A load-bearing structure comprising an elongated body subject to flexural stress in a given plane by the load, said body including a plurality of juxtaposed sections of substantially identical configuration each having a wall surface disposed substantially parallel to said plane, said sections having aligned passages defining at least one throughgoing channel; elongated, flexible and substantially inextensible tensioning means in said channel alternately tightenable and releasable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections being provided with clearances enabling at least partial displacement of said tensioning means along said wall surface between a region subject to negative stresses under load and a location remote from said region; and actuating means anchored to said tensioning means for alternately tightening and relaxing same.

2. A structure as defined in claim **1** wherein said sections are hingedly interconnected in the vicinity of said remote location.

3. A load-bearing structure comprising an elongated body subject to flexural stress in a given plane by the load, said body including a plurality of juxtaposed sections of substantially identical configuration each having a wall surface disposed substantially parallel to said plane, said sections having aligned passages defining at least one throughgoing channel; elongated, flexible and substantially inextensible cable means in said channel alternately tightenable and releasable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections being provided with clearances enabling at least partial displacement of said cable means along said wall surface between a region subject to negative stresses under load and a location remote from said region; cable-engaging means on said wall surface for maintaining said cable means in said region in the tightened condition thereof; and actuating means anchored to said cable means for alternately tightening and relaxing same.

4. A structure as defined in claim **3** wherein said cable-engaging means comprises peg means adjustably disposed on said wall surface.

5. A structure as defined in claim **4** wherein said wall surface is provided with a slot extending at an angle to said cable means, said peg means being displaceably received in said slot and selectively immobilizable therein in different positions.

6. A load-bearing structure comprising an elongated body subject to flexural stress in a given plane by the load, said body including a plurality of juxtaposed sections of substantially identical configuration with at least two mutually perpendicular longitudinal walls, one of said walls forming a surface disposed substantially parallel to said plane; elongated, flexible and substantially inextensible cable means alternately tightenable and releasable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections being provided with clearances enabling at least partial displacement of said cable means along said surface between a region subject to negative stresses under load and a location remote from said region; cable-engaging means on said wall surface for maintaining said cable means in said region in the tightened condition thereof; and actuating means anchored to said cable means for alternately tightening and relaxing same.

7. A load-bearing structure comprising an elongated body subject to flexural stress in a given plane by the load, said body including a plurality of juxtaposed sections of substantially identical configuration with at least two mutually perpendicular longitudinal walls, one of said walls forming a surface disposed substantially parallel to said plane; elongated, flexible and substantially inextensible cable means alternately tightenable and releasable for solidifying said body by aligning said sections

in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections being provided with clearances enabling at least partial displacement of said cable means along said surface between a region subject to negative stresses under load and a location remote from said region; cable-engaging means on said wall surface for maintaining said cable means in said region in the tightened condition thereof; and actuating means anchored to said cable means for alternately tightening and relaxing same, said one of said walls being provided with an internal longitudinal channel accommodating said cable means, the channels of all said sections being coplanar and forming the clearances for the displacement of said cable means.

8. A structure as defined in claim **7** wherein said cable-engaging means comprises an abutment fixedly disposed in said channel, said abutment contacting only a limited length of said cable means substantially midway within the channel in the tightened condition of said cable means.

9. A load-bearing structure comprising an elongated body subject to flexural stress in a given plane by the load, said body including a plurality of juxtaposed sections of substantially identical configuration each having a wall surface disposed substantially parallel to said plane; a pair of elongated, flexible and substantially inextensible parallel cables alternately tightenable and releasable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections being provided with clearances enabling at least partial displacement of at least one of said cables along said wall surface between a region subject to negative stresses under load and a location remote from said region; cable-engaging means on said wall surface for maintaining said cables in said region in the tightening condition thereof; and actuating means anchored to said cables for alternately tightening and relaxing same.

10. A load-bearing structure comprising an elongated body subject to flexural stress by the load, said body including a plurality of juxtaposed sections of substantially identical rectangular profile, said sections having aligned passages defining at least one throughgoing channel; elongated, flexible and substantially inextensible tensioning means in said channel alternately tightenable and relaxable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said tensioning means being confined at least in the tightened condition thereof to a region subject to negative stresses under load; actuating means anchored to said tensioning means for alternately tightening and relaxing same; and coupling means disposed between confronting faces of adjoining sections for positively interlinking same against relative lateral displacement in the aligned position of said sections, said coupling means including a general frustoconical bead slidable on said tensioning means, said bead being located at a corner of the rectangular profile at least in the tightened condition of said tensioning means, said sections being formed with internal clearances enabling at least partial displacement of said tensioning means in a plane parallel to two of the sides of said rectangular profile.

11. A structure comprising a collapsible frame which includes a pair of parallel bars each composed of:

- a plurality of juxtaposed sections of substantially identical configuration, said sections having aligned passages defining at least one throughgoing channel;
- elongated flexible and substantially inextensible tensioning means in said channel alternately tightenable and relaxable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said sections having confronting faces provided with aligned recesses, said tensioning means passing through said recesses at least in its tightened condition;
- a bead slidably mounted on said tensioning means between adjoining sections for entry into said recesses upon a tightening of said tensioning means, said bead being slidable on said tensioning means and tapering in opposite directions for entry into complementary recesses of said confronting faces;
- and actuating means anchored to said tensioning means for alternately tightening and relaxing same.

12. A structure as defined in claim **11** wherein said sections are of substantially rectangular profile, said bead being located at a corner of the rectangle at least in the tightened condition of said tensioning means.

13. A load-bearing structure comprising an elongated body subject to flexural stress by the load, said body including a plurality of juxtaposed sections of substantially identical generally rectangular profile, said sections having aligned passages defining a pair of throughgoing channels, a pair of elongated, flexible and substantially inextensible parallel tension elements in said channels alternately tightenable and relaxable for solidifying said body by aligning said sections in pressure-transmitting relationship and slackening said body by releasing said sections for limited relative displacement, said tension elements being confined at least in their tightened condition to two adjoining corners of the rectangle in a region subject to negative stresses under load; and actuating means anchored to said tension elements for alternately tightening and relaxing same, said sections being provided with clearances enabling a shifting of at least one of said tension elements towards a third corner of the rectangle.

References Cited by the Examiner

UNITED STATES PATENTS

736,104	8/1903	Hubartt	182—41
1,385,606	7/1921	Christensen	52—227
2,645,115	7/1953	Abeles	52—229
2,822,896	2/1958	Schuster	52—108
2,877,506	3/1959	Almoslino	52—227
2,902,789	9/1959	Mehr	43—18

FOREIGN PATENTS

531,975	8/1955	Italy.

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EXTENDABLE-RETRACTABLE BOX BEAM

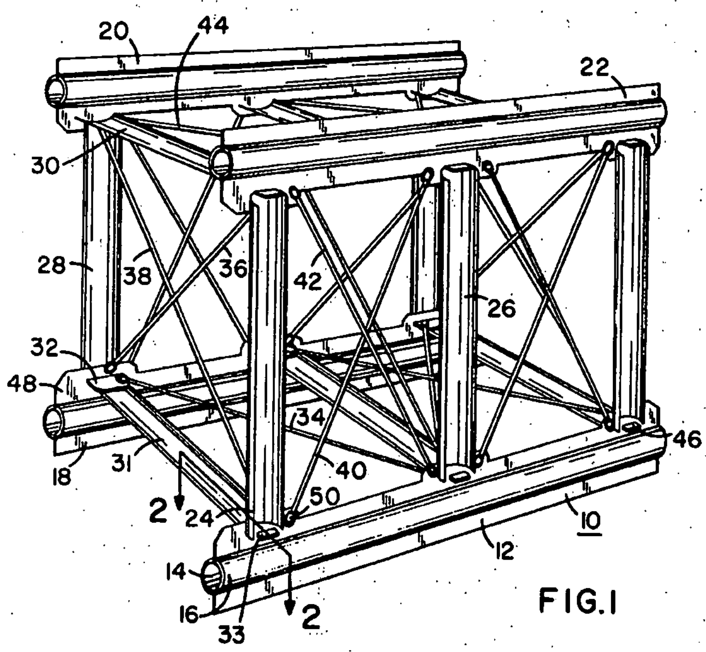

FIG.1

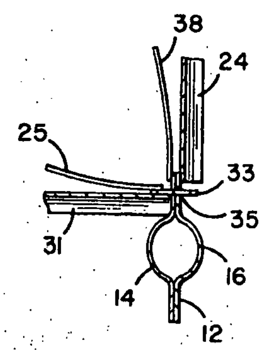

FIG.2

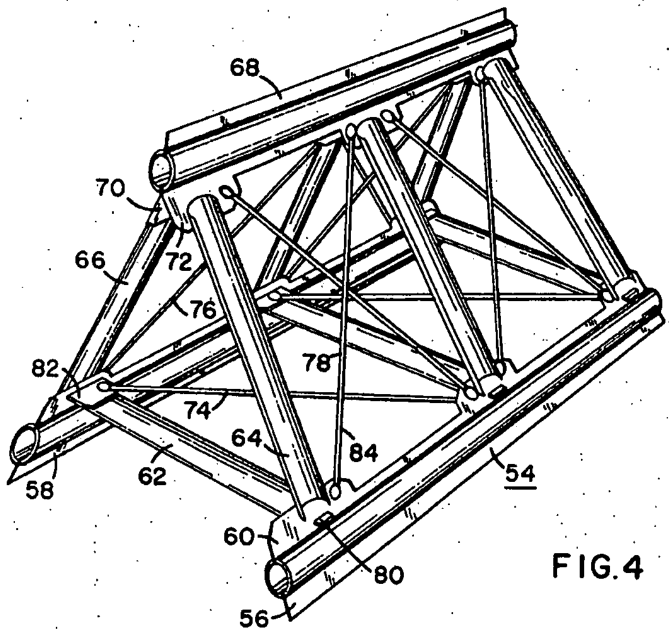

FIG.4

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EXTENDABLE-RETRACTABLE BOX BEAM

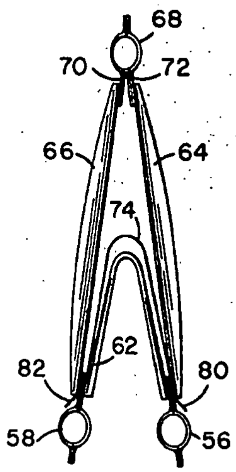

FIG.5

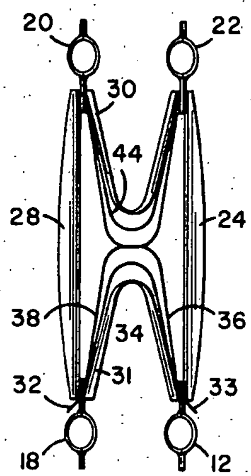

FIG.3

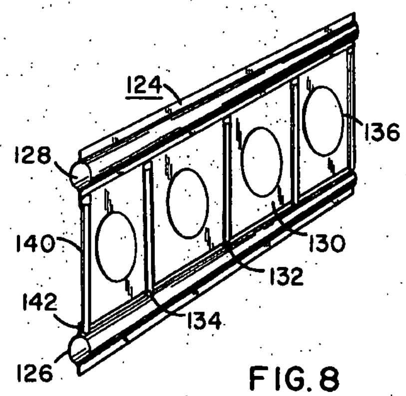

FIG.8

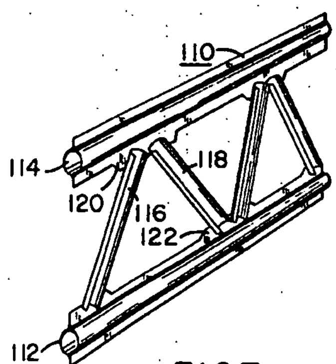

FIG.7

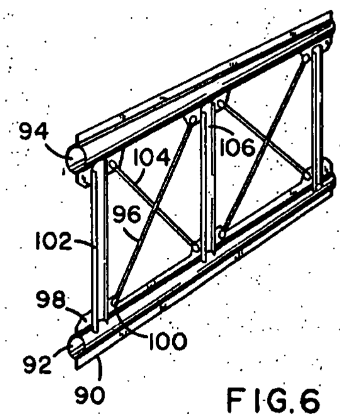

FIG.6

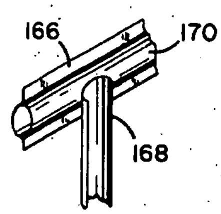

FIG.11

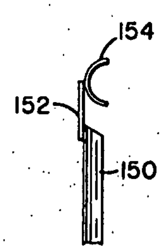

FIG.9

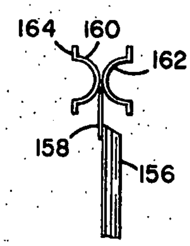

FIG.10

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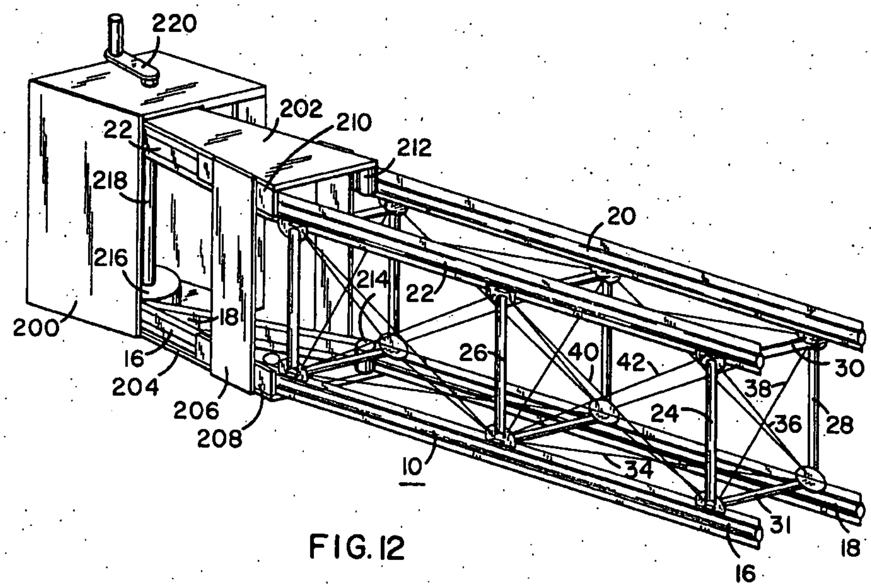

FIG. 12

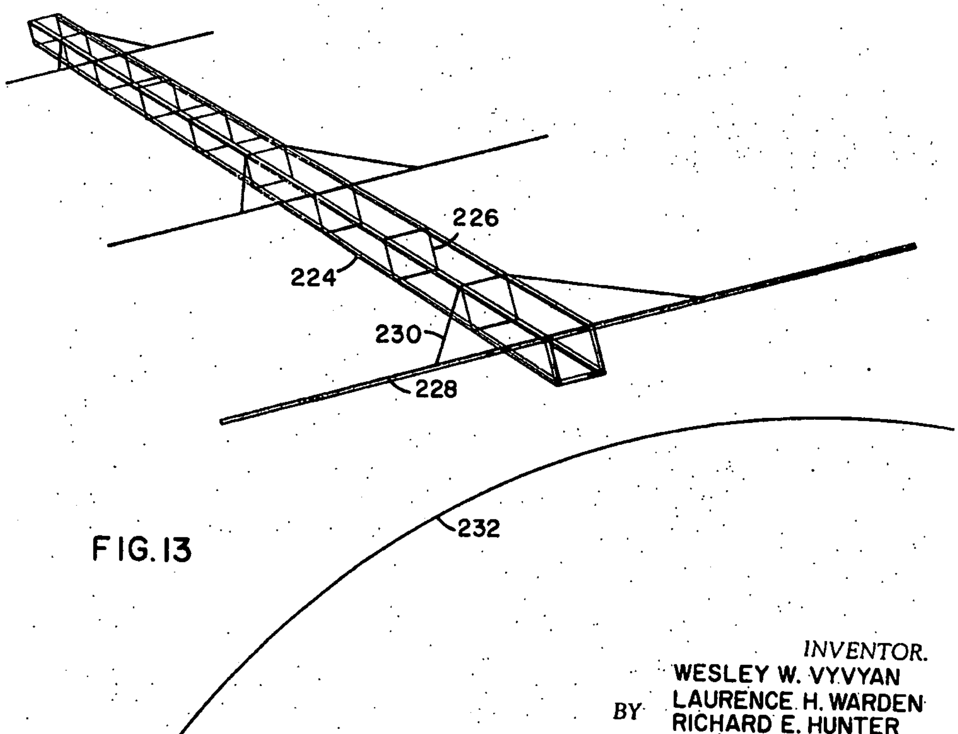

FIG. 13

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EXTENDABLE-RETRACTABLE BOX BEAM

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Int. Cl. E04h *12/10*
U.S. Cl. 52—108 15 Claims

ABSTRACT OF THE DISCLOSURE

An extendable and retractable box beam structure that may be collapsed into a coil shape and selectively extended and expanded to a longitudinal and linear structure that forms a rigid box beam structure.

The longitudinal structural members are of thin resilient material with a curved cross section and are collapsible to a generally flat configuration for rolling, but are self-erecting to a rigid form by their own resilience when unrolled. Intercostal members connecting the longitudinal members in a frame or beam structure are similarly resilient and collapsible, and return to their preformed configuration when released. Three or four sided box beams can be collapsed into a substantially flat rolled form by folding certain of the intercostals.

BACKGROUND OF THE INVENTION

There are many applications for spar and box beam structural members of various configurations for use in remote locations, such as in space. However, moving such structure members to remote locations presents considerable transportation problems that are particularly acute where strong and rigid structures are required. Yet it is necessary to transport the structures to the remote locations and to assemble the structure at the site, usually by joining together many small pieces into, for example, remote antenna structures, reflectors, telescope structures, booms for large vehicles and other similar structures. While such structures can be transported to remote locations in disassembled form and then assembled at the site, this presents obvious problems in space as it tends to be impractical to lift heavy structures even in piece form into space and it is even more impractical to assemble intricate structures piece by piece in space.

Thus it is advantageous to have extendable-retractable spar structures, beam structures and composite box beam structures that are easily packaged in a relatively small volume for storage and transportation and when extended and deployed, comprise a large, reliable and highly efficient structure that is light weight and strong and that can be used to construct many different structures in remote locations and particularly in space.

SUMMARY OF THE INVENTION

In specific embodiments of this invention, spar sections are constructed of upper and lower longitudinal cap members. The cap members have a relatively thin wall with a curved cross section that is collapsible in a plane normal to the longitudinal length of the cap members, to a relatively flat cross section. The spar members can be rolled onto a reel, without permanently deforming the spar structure. The longitudinal cap members are joined together along their length with rigid intercostals that are bendable in the same plane as the longitudinal cap members

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and that may comprise connecting structures that are similar to the longitudinal cap members or of thin material having semi-circular or contoured cross sections. The spar members may be connected together to form, for example a rectangular, extendable, retractable box beam or a triangular shaped box beam. Similar collapsible intercostals interconnect the respective spar sections of the box beam structure. Other intercostals comprising cables or thin straps are secured between respective portions of the cap members adding rigidity to the structure.

In one specific embodiment, the longitudinal cap members comprise aligned sides of thin, spring, sheet metal that are joined at their longitudinal edges and bow outwardly forming a substantially cylindrical configuration. While the aligned sides in the bowed condition are pressed together forming a substantially flat member that may be spiraled without deforming the spring material, the spring material when released, expands to the outwardly bowed condition forming a longitudinal structure that has considerable rigidity against torsional forces, bending forces, and shear forces. In another specific embodiment, the cap members comprise longitudinal strips of thin material having a semi-circular contoured cross section. The semi-circular cross section can be collapsed to a flat structure and spiraled on a reel. In still another specific embodiment, a pair of the longitudinal semi-circular contoured members are joined at their outer surfaces at the mid-point of their outer surfaces forming a collapsible structure that may be collapsed to a flat cross section and rolled on a reel or other mechanism.

All of these specific embodiments utilize flexible, preformed sections that are capable of deforming to flat, linear structures that are spiraled to a reduced volume. The structure may be rolled on a storage drum that is rotated by a power system or other suitable means. The drum, for example, is rotated clockwise and the box beam is unwound from the drum. The plane of the spiral beam extension is controlled by the location of support guides on the drum support, which guides are contoured to the shape of the cap elements. In retraction, the rotational direction of the drum is reversed and the cap elements are flattened by guide rollers and the box beam is wrapped in a spiral on the drum. The box beam cap may be constructed of metallic or non-metallic high strength material that is preformed to a desired expanded contour shape. The shape and thickness of the material is selected to fulfill the specific load requirements and to allow full element flattening without yielding or deforming the material.

It is therefor an object of this invention to provide a new and improved spar or box beam structure.

It is another object of this invention to provide a new and improved spar or box beam structure that is lightweight and yet forms a rigid, strong and highly efficient structure or structural element.

It is another object of this invention to provide a new and improved spar or box beam structure that is capable of being retracted into a small and compact volume.

It is another object of this invention to provide a new and improved spar or box beam structure that is lightweight, and yet provides a strong and rigid structure, that may be rolled onto a storage drum and extended from a storage drum into a fully assembled spar or box beam structure.

Other objects, novel features, and advantages will become more apparent upon a review of the following de-

tailed specification and an examination of the drawings in which:

FIG. 1 is a perspective view of a section of an extendable-retractable rectangular box beam structure of this invention.

FIG. 2 is a cross sectional view taken along lines 2—2 of FIG. 1.

FIG. 3 is an end view of the rectangular box beam structure of FIG. 1 in the partially collapsed condition.

FIG. 4 is a perspective view of a section of a triangular box beam structure of this invention.

FIG. 5 is an end view of the triangular box beam structure of FIG. 4 in the partially collapsed condition.

FIG. 6 is a perspective view of a section of a spar structure of this invention.

FIG. 7 is a perspective view of a section of a modified form of the spar structure of this invention.

FIG. 8 is a perspective view of a section of still another modified spar construction of this invention.

FIG. 9 is an end view of a structural element that is used to construct spars and box beams in this invention.

FIG. 10 is an end view of still another modified structural element that is used to construct spars and box beam structures of this invention.

FIG. 11 is a perspective view of still another structural element that is used to construct spars and box beam structures of this invention.

FIG. 12 is a perspective view of the means for extending and retracting the spars and box beam structures of this invention.

FIG. 13 is an illustrative view of the use of the retractable-extendable box beam structure of this invention as an antenna structure in space.

Referring now to FIG. 1, a rectangular extendable-retractable box beam structure **10** has four longitudinal cap members **12, 18, 20** and **22.** These cap members may be made of any suitable thin spring material that is metallic or non-metallic, such as steel, titanium, plastics or fiberglass, or other suitable materials. The cap members comprise aligned sides **14** and **16** of thin spring material that are joined at their longitudinal edges and that bow outwardly having an open internal volume forming a cylindrical configuration. This cylindrical configuration is collapsible to a substantially flat structure in the plane of the longitudinal edges by applying force against the sides **14** and **16.** When the sides of the bowed out portions are collapsed inwardly, the cap members become a substantially flat member that may be rolled into a spiral onto a drum, reel or other suitable device. This rolling does not deform the cap members. Thus when the cap members are rolled off the reel, the side members **14** and **16** spring outwardly forming the cylindrical cap members that have longitudinal rigidity, and resistance against shear forces and torsional forces.

Intercostal members **24, 26,** and **28,** for example, are spaced along the length of the cap members and are normally made of the same or similar material that was used to make the cap members. The intercostals have a semi-circular contoured cross section and are rigidly connected at their ends to raised portions **48** on the edges of the cap members. The intercostal members **24, 26,** and **28** may be rigidly joined to the cap members by welding, braising, bonding or by other suitable known techniques.

Horizontal intercostal or web members are secured to the adjacent sides of the cap members. The intercostal members 30 and 31 have the same configuration as intercostal members 24 and 26, except that the horizontal intercostal members have plates **32** braised, welded, or bonded to the upper, center, outer surface at their opposite ends. The plates **32** have end tabs **33** that project through slots in the raised edge portions **48** that secure the ends of the intercostal members **30** and **31** into abutting position against the surfaces **48.** This allows the ends of the intercostal members **30** and **31** to pivot upwardly upon the contraction or collapsing of the beam structure.

Other intercostal members comprise cables **34, 36, 38, 40** and **42** that connect across the box beam structure and form a restraining support. These other intercostal members can be cables or thin strips of metal. They are secured in any suitable manner to the raised portions **48** and to the plates **42** such as by end extensions that are fastened by resistance welding, bonding, gussets, or in any suitable manner.

The box beam structure of FIG. 1 may be collapsed by a suitable reel structure and mechanism, see FIG. 12. A representative structure for rolling in, retracting or extending the box beam structure has a housing **200** with an opening in one side. Positioned in the housing is an axle **218** with upper and lower reel wheels **216.** The axle **218** and the reel wheels **216** are turned by a crank **220.** Extending from the opening is an upper plate **202** and a lower plate **204,** that are secured together by side plates **206.** Guide plates **208** and **210,** that may be made of teflon or other suitable materials, are secured to the side plates **206.** Rollers **212** and **214** are secured to plates **202** and **204** in a position adjacent the plates **210** to impart compressive force against the cap members **12, 18, 20** and **22.** The intercostal members **206** are rolled into the guide plates and are flattened out on the reel through compressive force. The cables **42** and the horizontal intercostal members **30,** see FIG. 3, bend inward and are supported within the collapsed box beam structure **10.** The entire box beam structure is collapsed into a relatively flat structure that is rolled on reel **218** and around the reel wheels **216,** with the entire structure being reeled into the enclosed box structure **200.** While the reel is illustrated as being turned by crank **220,** it may be understood that the reel structure can be rotated by any suitable mechanical means such as a motor or other suitable mechanism.

FIG. 2 illustrates the cross sectional structure of the cap member **12** and the expanded sides **14** and **16** with the slot **35** therethrough that receives the tab end **33.** FIG. 3 illustrates the box beam structure of FIG. 1 in the partially collapsed condition. The horizontal intercostal members **30** and **31** are bent in an upward and downward direction and the cables **34, 36, 38, 40** and **42** are carried in an upward and downward direction by the movement of the horizontal intercostal members **30** and **31.**

The box beam may also be constructed as a triangular box beam structure as illustrated in FIG. 4. In this embodiment the upper single, cap member having diverging edge portions **70** and **72** to which are secured the ends of the vertical intercostal members **64** and **66.** Also in this embodiment, the flexible intercostal members **78** comprise this strap material that may be made of metal similar to the metal or material used in making the cap members and the other intercostal members. The triangular shaped box beam of FIG. 4 may be collapsed in the same manner as illustrated in FIG. 12 wherein the rollers **212** and the upper plates **210** are moved to the center of the plate **202.** FIG. 5 illustrates the triangular shaped box beam of FIG. 4 in the partially collapsed condition with the center intercostal members **62** bowed upwardly and the strap members **74** pushed in an upward direction.

It maybe understood that the box beams of FIGS. 1 and 4 may be constructed from several different spar stuctures or the spar structures, per se, may be used as extendable and retractable structural members for any given structure. Examples of modified forms of the spar structures are illustrated in FIGS. 7, 8, 9, 10, and 11. The spar structure of FIGS. 1 and 4 are illustrated in FIG. 6. The spar structure **90** has a lower cap member **92** and an upper cap member **94** with intercostal members **102** and **106** that are secured to raised edge portions **98.** Cables **96** and **104** provide the restraining cross support of the spar structure. with reference to FIG. 7, the spar structure **110** comprises a lower cap member **112** and an upper cap member **114** with diagonal intercostal members **116** and **118** that have the curved semi-circular

structure as previously described. In this embodiment, the cable or strap intercostal members are eliminated.

In the spar structure **124** of FIG. 8, the intercostal members comprise sheet material **130** having support pieces **132** and **134** that are secured at their longitudinal outer surface to the sides of the sheet members **130**. The sheet members **130** have open spaces **136** to reduce weight, and the edges of the sheet members are secured between the adjacent longitudinal edges of the upper and lower cap members **126** and **128**. In other modified spar constructions, the cap members may comprise a longitudinal member **154**, see FIG. 9 made of thin material having a semi-circular contoured cross section as previously described relative to the intercostal members **24** and **28**. An intercostal member **150** is secured to the semi-circular contoured cap member **154** by a plate member **152** that is secured to the center portion of the outer surface of the end of the intercostal member **150** to the centered side surface of the outer surface of the cap member **154**. Referring to FIG. 10, the cap member comprises a pair of longitudinal semi-circular contoured cross section members **160** and **162** that are joined at their adjacent centered outer surfaces and have outwardly directed longitudinal edge portions **164** that provide added rigidity to the cap structure. Plate members **158** are secured between the adjacent surfaces of the contoured section **160** and **162** and have a downward portion that is connected to the outer centered surface of the intercostal member **156**. In FIG. 11 the intercostal member may be secured by braising, welding, or the like to one of the outer side surfaces of the cap structure that comprises the thin sides of spring material that are joined at their longitudinal edges and that bow outwardly. Each of the foregoing structures may form a separate spar sturcture or may form a spar structure used in the box beam structure as illustrated in FIG. 1 or 4, each of which can be collapsed into a retractable structure on a reel as illustrated in FIG. 12.

In operation, the aforesaid box beam structures or spar structures are retracted into a small light weight volume and transported to any place of use, such as in space. The structure is then extended to be used to make any suitable composite structure such as illustrated in FIG. 14, where a rectangular box beam structure **224** having intercostals **226** functions as an antenna structure having diapoles **228** that have support lines **230**. The structure is extended in space above the earth **232**.

Thus it may be understood that large structures can be packaged in a small volume and yet the structures when extended have exceptional strength characteristics against bending, sheer and torsion forces. The dynamic launch force and storage volume requirements are completely minimized for spacecraft applications. The simplicity of the structure provides maximum reliability with only a small force required to extend and retract the box beam structure.

Having described our invention, we now claim:

1. An extendable-retractable box beam that is selectively collapsible to a reduced volume in the retracted condition and extendable to rigid box beam structure comprising:

at least three longitudinal cap members each having relatively thin resilient walls with a normally curved cross section that is forcibly collapsible to a relatively flat cross section in a given plane,

said cap members in the extended position being parallel in the longitudinal direction and spaced from each other,

and spaced intercostals of resilient material with a normally curved cross section that are forcibly bendable in a given plane interconnecting said cap members in space defining relationship, said spaced cap members and spaced intercostals forming a box beam in the extended condition.

2. An extendable-retractable box beam as claimed in

claim 1 in which said cap members comprising aligned sides of thin spring material that are joined at their longitudinal edges and that bow outwardly forming a cylindrical configuration that is collapsible to a substantially flat configuration in the plane of said longitudinal edges, said intercostals being secured to the joined edges of said sides.

3. An extendable-retractable box beam as claimed in claim 1 in which the ends of certain ones of said intercostals are fixedly connected to said cap members at spaced intervals along the length thereof, forming adjacent ribs.

4. An extendable-retractable box beam as claimed in claim 3 including the ends of others of said intercostals are pivotally connected at spaced intervals between said cap members, forming adjacent ribs.

5. An extendable-retractable box beam as claimed in claim 3 in which the ends of said certain ones of said intercostals are secured to the adjacent longitudinal edges of said cap members by the convex outer surface of the intercostals.

6. An extendable-retractable box beam as claimed in claim 3 in which the ends of said ones of said intercostals being secured to the outer surface of one of the bowed sides of the said cap members with the outer convex surface of said intercostals abutting said outer surface of said bowed sides.

7. An extendable-retractable box beam as claimed in claim 4 in which:

the end edges of said others of said intercostals abutt the adjacent sides of adjacent longitudinal edges of said cap members,

and tab plates secured to the outer center surface of said others of said intercostals with end projections that project pivotally through slots in said longitudinal edges of said cap members.

8. An extendable-retractable box beam as claimed in claim 1 in which said cap members and said intercostals comprise members of thin material having semi-circular contoured cross sections.

9. An extendable-retractable box beam as claimed in claim 8 including plate members secured to the outer convex surface of said cap members and to the outer convex surface of ends of said intercostals for fixedly securing said cap members to said intercostals.

10. An extendable-retractable box beam as claimed in claim 1 in which:

each of said cap members comprising a pair of longitudinal members of thin material having semi-circular contoured cross sections with the outer convex surfaces of said longitudinal members being joined together,

and said intercostals comprising members of thin material having semi-circular contoured cross sections.

11. An extendable-retractable box beam as claimed in claim 10 in which the outer longitudinal edges of said semi-circular contoured cross sections have substantially flat longitudinal edge portions that are angled outwardly from the semi-circular contoured cross section portions.

12. An extendable-retractable box beam as claimed in claim 11 including plate members having one side secured between the adjacent convex surfaces of said longitudinal members of said cap members and the other side secured to the outer convex surface of ends intercostals for fixedly securing said cap members to said intercostals.

13. An extendable-retractable box beam as claimed in claim 1 and including a sheet of resilient material with side edges secured to and connecting adjacent ones of said longitudinal cap members, said intercostals being secured by their outer convex surfaces to said sheet material substantially normal to the longitudinal length of said cap members, forming rib sections.

14. An extendable-retractable box beam as claimed in claim 1 in which, said box beam includes one upper longi-

tudinal cap member and a pair of lower cap members forming a triangular shaped box beam, the intercostals connecting said lower cap members being foldable upwardly for collapsing the box beam to a substantially flat condition.

15. An extendable-retractable box beam as claimed in claim 1 in which said box beam having a pair of upper longitudinal cap members and a pair of lower cap members forming a rectangular box beam, the intercostals connecting said cap members along two opposed sides of the box beam being foldable inwardly between the other sides.

References Cited

UNITED STATES PATENTS

1,115,491	11/1914	Bindley et al.	52—646
1,677,577	7/1928	Amiot	52—731
2,130,993	9/1938	Dubilier	52—108
3,258,800	7/1966	Robinsky	52—108
3,385,397	5/1968	Robinsky	52—108
3,434,254	3/1969	Rubin	52—108
3,474,579	10/1969	Kieser	52—108
3,486,279	12/1969	Webb	52—108

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U.S. Cl. X.R.

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